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4. TITLE AND SUBTITLE
(AASERT-97) (BMDO) Modeling & Simulation of Multiwavelength Conversion in Semiconductor Laser Optical Amplifiers for Logic, Switching, Communication

5. FUNDING NUMBERS
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6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE, DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This grant was an AASERT funded project that supported one graduate student in association with parent grant F49620-96-1-0168. The program achieved several wavelength conversion demonstrations via four-wave mixing in semiconductor optical amplifiers (SOAs) and computer simulation to describe multiwavelength propagation in SOAs with wavelength dependent gain and gain saturation. They studied the effect of generation of composite dynamic gratings on the FWM wavelength conversion process and demonstrated the following FWM milestones: single channel conversion of 12.5 Gbps pseudo-random bit sequence (PRBS) data, single pump/multichannel probe conversion of four 2.5 Gbps channels and simultaneous conversion of two 2.5 Gbps data channels using two spectrally segmented FWM process within a single amplifier. The later demonstration represents a significant milestone in the direction of our program objectives. The team also implemented several models for multiwave propagation in SOAs that account for wavelength dependent gain asymmetry, saturation power, small signal modulation, and pulse propagation.

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14. SUBJECT TERMS

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AFOSR FINAL PROGRESS REPORT

Grant Number F49620-95-1-0466

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1. Objective:

This grant is an AASERT funded project that supports one graduate in association with parent grants Grant Number F49620-96-1-0168.

2. Status of effort:

The final status of this project includes several wavelength conversion demonstrations via four-wave mixing in semiconductor optical amplifiers (SOAs) and computer simulation to describe multiwavelength propagation in SOAs with wavelength dependent gain and gain saturation. We have studied the effect of generation of composite dynamic gratings on the FWM wavelength conversion process and have demonstrated the following FWM milestones: single channel conversion of 12.5 Gbps pseudo-random bit sequence (PRBS) data, single pump/multichannel probe conversion of four 2.5 Gbps channels and simultaneous conversion of two 2.5 Gbps data channels using two spectrally segmented FWM process within a single amplifier. The later demonstration represents a significant milestone in the direction of our program objectives. We have also implemented several models for multiwave propagation in SOAs that account for wavelength dependent gain asymmetry, saturation power , small signal modulation, and pulse propagation.

3. Accomplishments/New Findings:

3.1. Distributed FEM Model

We have developed a wave propagation simulation program for an SOA using a distributed wavelength dependent gain model. Starting with the quasi-steady state carrier density equation that accounts spontaneous emission (i.e. nonradiative, radiative and Auger recombination) and stimulated emission, the total electric field is propagated in z-direction through the amplifier. We keep track of carrier density and

resulting gain and index for each distributed section in the amplifier. Complete wavelength dependence is maintained.

3.2. Carrier Density Equation and Gain Flattening

. It is well known that Auger recombination is an important effect in long wavelength semiconductor devices. As opposed to other models, we do not attempt to find an analytical solution for the nonlinear carrier density equation. Instead we solved the quasi steady-state carrier density equation numerically. This makes it possible to retain the effects of Auger recombination on the carrier density. As a result, the gain flattening as a consequence of gain saturation in the amplifier can be modeled more accurately. The results of this research will be presented at the LEOS topical meeting Nov. 1997 [3].

3.2.1. Time dependent Model

. We have generalized steady state model to include the temporal behavior of FWM effects in SOAs. We demonstrate fluctuations in carrier density as a result of electric fields of slightly different frequencies beating within the semiconductor material. We are currently developing a novel composite grating view of this process to aid in understanding how multiple FWM processes operate within the same SOA gain medium.

3.2.2. Two pump-probe Model

. The results of a two-pump-probe model are complete and are reported in a thesis by Chris Scholz.

4. Personnel Supported:

. **Graduate Students:** Chris Scholz
. **Research Engineer:** Laurent Dubertrand
. **Postdoctoral Fellow:** Nitin Kothari
. **Faculty:** Daniel J. Blumenthal

5. Publications:

. [1] C. J. Scholz, L. Dubertrand and D. J. Blumenthal. Two Independently Controlled Wavelength Conversions Using Four-Wave Mixing in a Single Semiconductor Optical Amplifier. Submitted for publication in *IEEE Photonics Technology Letters,* 1997.

. [2] C. J. Scholz, L. Dubertrand and D. J. Blumenthal. Demonstration of two Simultaneous Independently Controlled Wavelength Conversions Using a Novel Dual-Pump/Dual-Probe Four Wave Mixing Configuration. To be presented at the *LEOS 10th Annual Meeting,* San Francisco, Nov., 10--13, 1997

.   [3] C. J. Scholz and D. J. Blumenthal. The Influence of Wavelength Dependent Distributed Gain on the Optical Bandwidth of Semiconductor Optical Amplifiers. To be presented at the *LEOS 10th Annual Meeting*, San Francisco, Nov., 10--13, 1997

.   [4] N. C. Kothari and D. J. Blumenthal, "Influence of gain saturation, gain asymmetry, and pump/probe depletion on wavelength conversion efficiency of FWM in semiconductor optical amplifiers," *IEEE Journal of Quantum Electronics*, Vol. 32, No. 10, pp. 1810-1816, Oct. 1996.

.   [5] D. J. Blumenthal and N. C. Kothari, "Semiconductor Optical Amplifiers," Chapter 61, The Communications Handbook, Eds. J. D. Gibson, CRC Press Inc., 1996.

6.   Interactions/Transitions:

.   **a.**

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. Program Committee	Optical Fiber Communications Conf.	1997, 1998
. Chair	Atlanta Chapter of the LEOS/ED	1996-1997
. Program Committee	OSA Top. Mtng. on Photonics in Switching	1997
. Program Committee	IEEE/LEOS WDM Component Technol.	1997

.   Invited Talk: D. J. Blumenthal, "Coherent Crosstalk in Photonic Switched Networks," Topical Meeting on Photonics in Switching, April 1-4, Stockholm, 1997.

.   Invited Talk: D. J. Blumenthal, "Physics and applications of semiconductor optical amplifiers," IEEE/LEOS Annual Meeting, Nov. 18-21, Boston, 1996.

.   **b.**
.   Naval Research Laboratory: Invited seminar on multiwavelength communications, switching, tunable lasers and microwave photonics. April 21, 1997. Joe Weller and Ron Esman.

7.   New discoveries, inventions, or patent disclosures.

.   None

8.   Honors/Awards:

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. Young Investigator Award	Office of Naval Research	1997
. Associate Editor	IEEE Photonics Technology Letters	1997